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# THE BORDER-LAND OF SCIENCE.

### BY R. H. THURSTON, DIRECTOR OF SIBLEY COLLEGE, CORNELL UNIVERSITY.

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EVERY intelligent reader and thinker who has studied the history of those marvellous developments of physical science which have characterized the progress of civilization during the last half-century, and who continues to watch the wonderful acceleration of its progress, which seems to-day its most striking feature, must inevitably recognize in its growth an element of vastly greater importance than the merely material and utilitarian side which so disturbed the mind of the eccentric and unfortunate, but always artistic and poetical, Ruskin. Science has been to the world a great comforter, civilizer, and enlightener. It is a moral as well as a physical agent, promoting morality as well as aiding humanity in its physical and intellectual progress. It has generated "sweetness and light" as well as those coarser, but no less essential, elements of our onward and upward movement which seemed to Matthew Arnold so insignificant. Its growth and its effects have been like those of that light described, in Genesis and by Geology, at the beginning of the world's history. At first glimmering, faint, uncertain, hardly visible, exhibiting to the senses only the fact of the existence of infinite darkness, it has gradually spread over the world, growing brighter as it expanded; enlightening wider and wider areas; revealing the good to be sought, the bad to be evaded; its brightness increasing more and more rapidly this side the "dark ages," until we are more than satisfied with the brilliancy of its rays; and as we endeavor to accustom ourselves to the sunlight of our own century, we wonder if it be possible that the race can adapt itself to the requirements of further progress.

But as the light gains in intensity and illuminates more and more brightly the world about us, and as it extends its enlightening rays further and further into the dark regions that always border its field, there always exists a border-land, more or less distinctly seen and more or less defined, in which are included those wonders which we may hope yet to see. We continually marvel at the inventions and discoveries of to-day, and wonder still more what will come to-morrow. We are continually expecting to see a limit reached by the inventor and by the discoverer, and are as constantly finding that we are simply on a frontier which is being steadily pushed further and further out into the infinite unknown; and the more we learn and the more we discover, the greater the opportunity for greater and more rapid progress. We are daily learning a more thorough appreciation of our own ignorance and of the insignificance of our finite in the midst of the infinite. We have groped our way with our rushlight, have made better speed with the modern candle, have congratulated ourselves on the excellence of our oil-lamps, have boasted of our gas-lights, and now take exceeding pride in the radiant brightness of our electric lights; yet we are far from an approximation to the volume, the intensity, and the quality of sunlight, and can see that the path ahead is still too long for our measurement, and that, in comparison, the distance already traversed is microscopic. The border-land is still ahead of us, constantly enlarging as we move on. The more we gain, the more is seen to be achievable.

The progress observed by the student of history from rushlight to electric light, and from barbarism to civilization, has always been an accelerated motion. From insignificant beginnings we have seen the race advance by a movement, slow at first, gradually increasing, continually gaining in rate of motion as well as in position, until, especially during the last generation, the velocity of onward movement has been such that the brightest intellect, the most powerful mind, is utterly unable to follow it in all its paths, and every worker and every student has become a specialist. Each is well content to contribute his mite to the general treasury and to assist by aiding ever so little through his labors in his own restricted field. No Humboldt can ever again grasp the whole of existing pantology; no Bacon can ever again hope to see the limits of the ever-widening field; no Compte can ever again safely attempt to plan a scheme for the development of all minor lines of scientific investigation.

Excursions into the border-land of science must hereafter be planned and conducted by men who have already made themselves familiar with the previously-explored adjacent territory; and we find that the accelerated progress of the past and of the present is likely to be assured by a greater and greater body of such specialists. A hundred philosophers follow Bacon; a thousand seek the ends proposed to them by Compte ; and innumerable scientific students and investigators endeavor to make known the unknown by entering upon the paths of which the beginnings were revealed by earlier Humboldts. A few years ago Faraday studied chemistry and physics; to-day he would be either a very stupid or a very rash man who should claim to be at once chemist and physicist. In the last generation we had chemists and physicists; to-day the chemist finds ample scope for all his powers in the study of the molecular structure of an organic compound, or in the investigation of the petroleums, or in the examination of the effects of varying proportions of manganese upon the properties of the modern "mild" steels; while the physicist has become an electrician, a student of the spectra, an investigator of the form of the sound-wave; or he studies the conditions affecting the liquefiability of the so-called "permanent" gases. Thus specializing, he becomes competent to attempt researches in the border-land of his science and to attack problems now vaguely looming up ahead like great icebergs, far away on the distant sea, obscured by their own mists—problems which are even grander and more important than those which the nineteenth century has already seen solved.

Thus, as a glance at the history of the past and its progress toward the present readily shows, the movement of the great current, while always more or less variable in rate and in direction, under the irregular action of impressed forces, has always, on the whole, been onward, and with, on the whole, an accelerated motion. The forces which have acted to modify, to change, to retard, or to accelerate this progress have been as apparently variable as those of the winds and the tides ; but, like those of wind and tide, every force so acting, whether moral, physical, or intellectual, has been controlled by law, and the resultant effect has always and invariably been an onward motion, with continual acceleration.

Looking back, then, upon this past of the race, we have seen mankind emerge from barbarism, become civilized and enlightened, growing in every possible direction of application of his faculties; passing through a long period of slowly-progressing advancement with still less easily perceived acceleration; gaining a hold upon one after another of the sciences and the arts; securing, one by one, the means of self-preservation and self-aid; all through the middle ages working for safe and stable forms of government; finally, after a certain stability had been reached, entering upon an era of thought and scientific investigation that was like the action of a new impulsive force driving the peoples of Europe along their rising pathway toward higher and greater life, with a now more and more perceptible gain in rate of motion. A century ago, the first fruits of the first efforts of scientific investigators of the preceding century began to be seen; and since the days of Lord Bacon and of Shakespeare, of Milton, and of Boyle and Young, into and through the times of Lavoisier, of Humphrey Davy, of Rumford, and of Faraday and Watt, of Stephenson, Fulton, Morse, and Wheatstone, of Stevens and Evans, and of the wonderful train of discoverers in science and of inventors in the arts who accompanied and followed those pioneers in exploration of all the innumerable fields opened by them in the last and in the present century, this acceleration has been more observable than ever before, and its effects have been more than ever impressive in their magnitude and in their results in the promotion of the welfare of humanity.

The centenarians of to-day—and they are more numerous than we commonly think—have seen the growth of nearly all that makes modern life. They saw the steam-engine introduced and applied to the turning of the busy wheels of countless mills, producing all the fabrics and all the apparatus essential to our life and comfort. They saw the railway laid in lines of iron and steel across continents, and forming bonds of far more strength than any treaties to hold State to State and to preserve the nation and the liberties for which our fathers and our grandfathers fought and died. They saw the inception and all the growth of steam navigation, and the construction of ships of continually increasing magnitude and speed, crossing the oceans like mighty shuttles, weaving the web of union between countries separated by thousands of miles of seas, and netting all nations in a community of interests that shall, in good time, become the grandest and most efficient safeguard against internecine feuds, and the most effective security against that most terrible and most shameful of all "relics of barbarism"—War. They have seen the lightning captured and harnessed for the noblest purposes of life, giving man conference with man across continents and seas, carrying his messages under the Atlantic, over all Europe and Asia, among the islands of the Indian and Pacific oceans, and under thousands of miles of water and over thousands of miles of land to farthest Australia. They have seen all energies converted to the use of mankind. They have seen the stored heat-energy of the rays of the sun, converted, as they were, millions of years before man came on this planet in visible form, reconverted into power and applied by the steam-engine to the production of electricity, and this new force set at work to transmit power over the world, to give us light in our streets and dwellings, and to the production of new forces in endless ways.

On these great forces which are the life of industry, the vital forces of steam and of electricity, are resting all the social edifices of modern life. All that we eat, all that we wear, our houses, every comfort, and all our luxuries are brought us to-day by these invisible, but almost omnipotent, genii of the fire and the lamp and the thunder-storm. The steamboat, the railroad, the telegraph, the telephone, the modern printing-press, all our machinery of the arts, and every recent invention and applied scientific principle, are brought us or are worked for us by them. The result is that our humblest neighbors, having health, and with habits of industry and wise forethought, may readily gain such comforts, and such once so-called luxuries, as no royal family could boast in the days of our grandparents—comforts and luxuries that were not then in existence and which no wealth could then procure. A nation may now become educated; a people may now be safe against poverty or famine; the world is even now, probably, past the critical point and sure of unintermitted future progress.

What more can we ask? What more may we expect? What more have we any right to hope for? Is this advance to be never-ceasing? What does science and what does the judgment of wise men justify us in hoping for? What are the discoveries and the inventions that science and art may be expected to give us in the future? These questions cannot, as a matter of course, be fully or definitely answered; but it is, perhaps, possible to obtain some idea of the extent and direction of this motion of the life of Man, this approximately, if not accurately, straight line of progress, for a little way ahead. We may, at least, ask what is the path now open, and what may we hope to find as we advance a little way further along it. Perhaps we may even be allowed to indulge in some speculation, if we carefully endeavor to distinguish between the results of our "scientific use of the imagination" and the reasonable deductions of permissible argumentation. We will take our speculations first and our more thoroughly founded deductions afterwards.

I am always inclined to ask, first, what may we believe to be the probable form and likeness of the coming man and his wife. I imagine that, when we look back from our home in the unseen universe, ages hence, we shall see, without much doubt, a race of men differing from those of to-day much as the man of to-day differs from his simious, perhaps simian, ancestors. The brain will be developed to meet the more complex and serious taxation of a more complex and trying civilization; the vital powers will be intensified; the man, reducing the powers of Nature still more completely to his service, will depend less on the exertions of his muscles, and they will be correspondingly and comparatively less powerful, though they will probably, nevertheless, I imagine, continue to grow somewhat in size, as they unquestionably have grown since the middle ages; the lungs must supply aëration to a larger and more rapidly circulated volume of blood richer in the phosphatic elements especially needed for the building-up of brain and nerve; the digestion must supply its nutriment in similarly increased amount and altered character and composition; the whole system must be capable of more rapid, more thorough, and more manageable conversion of the energies of the natural forces to the uses of the intellect and the soul which inhabits it.

If so much be granted, it is easy to see something of the nature of the change in the physical man that must gradually take place. The brain will enlarge in its anterior even more than in its posterior parts, and the great forehead will probably overhang a heavy but mobile face, having a god-like intelligence of countenance; with eyes large and prominent; with large nostrils; with a set of jaws at once fitted for the reduction of grain foods to pulp and to give basis for muscles capable of expressing great ideas by word and by play of feature. The chest will be large; the lungs capacious and free in operation, promptly self-adjusting to all demands and all variations of demand, and fitted to aërate enormous volumes of fluid flowing in from the veins. The digestive organs will necessarily be suited to develop and apply the phosphatic nutriment of grain and fruit foods; the liver, and spleen especially, producing those fats which make the main part of brain and nerve tissue—the abdomen thus growing with the lungs. The limbs may probably be longer; better cushioned with fat than now; smaller in proportion to the rest of the body, as to weight at least; though we may presume that this change will be made with positive gain, on the whole, in grace and general power. A more generally intelligent race will pay more attention to the preservation and cultivation of the physical powers by exercise and every sanitary device, and this will unquestionably aid in the development of a noble physique. The coming man will be tall, and free and lofty of carriage, as will befit a being full of noble thoughts and high aspirations, and his progress toward the infinite in all that is good and great will be commensurate with his ennobled powers of body and mind.

The woman of the coming race will have a similar development. Mind and body altering in similar directions, her intellectual face and her noble head will be carried above a no less impressive form. Ages of further growth of her always-controlling affections will have conferred upon her, even more than upon her consort, those beautiful perfections of manner and those attractions of face and figure, coming of the freer and freer play of the affections and graces of home, which must always distinguish in a superlative degree the lovelier sex. She will grow with the ages and through the ages; her form will gain in grace and strength, in roundness and beauty; and she will, as always, lead man in his approach toward heaven. Easier lives and more intelligence, a better application of knowledge, and in all respects a better life, will give to both the most that nature can confer. As evil dies and virtue survives and strengthens, they will, hand in hand, advance continually, and with continually greater ease and speed, toward the perfect life.

"What may we hope from science?" No man can say; but perhaps vastly more than the most sanguine to-day venture to predict. We have seen steam applied to the propulsion of the steamship and the railway train. Within a few years the steamboat has grown from the dimensions of a yacht to the size of the "Great Eastern" and of the "Sardegna" and the "City of Paris," driven by the power of 15,000 to 20,000 horses, crossing the Atlantic in less than a week. Another generation or two may see the size doubled and speed still further increased, the voyage reduced to less than four days. What all this means it is difficult to conceive; but perhaps it may aid the imagination to say that the engineer's horse-power is about a half more than the actual power of the average horse; that the engineer's horse works unremittingly twenty-four hours a day, and thus does the work of three real horses; that this means that he must find a way to stow the equivalent power of about a quarter of a million of horses in his ship of the next generation; that he must put the power of nearly 150,000 tons of horses into 8,000 tons of engine; that he must snugly pack in a ship 1,000 feet long, or perhaps less, the power of a "string-team" 500 miles long. But all this seems perfectly possible, and not altogether improbable, to the hopeful engineer of to-day. He thinks it may prove to be only a matter of time and money.

On land, steam is likely yet to show powers that may astonish the spectator of its performances as much as at sea. Speeds of sixty miles an hour and over have been already frequently attained, and there seems no reason to doubt that this is but a beginning. Boys living to-day may very probably see speeds exceeding a hundred miles an hour attained, and the continent crossed in two days or less. In fact, I have reason to believe that a speed of ninety miles an hour has already been maintained by an ordinary engine and light train for a short distance, with one of my over-bold boys at the throttle-valve; and it may not be long before engines are built for such speeds. Such an engine leaving New York in the morning would reach San Francisco the next night. But before this can be done much work will be required on the road-bed, as well as in the improvement of the machine itself. The engineer, however, given the demand and the capital, can unquestionably find ways of securing such speeds and maintaining them continuously and with safety.

But both these advances may become commonplace beside other wonders that we may reasonably believe possible to the wonder-working mind and hand of man, to the inventor and the mechanic aided by all the resources of modern and future sciences.

We are already familiar with the telegraph, transmitting messages across land and under sea around the world; we have even discovered a method of sending over its wires the *fac simile* of a written, or a printed, or an engraved page; the hand which writes a letter at one end of the line is imitated at the other by the pen of the lightning, and his every line, curve, and dot and dash exactly reproduced under the eye of his waiting correspondent. Who knows but that the time may come when his portrait may go with his letter, or even the words of his mouth, sent through line of telephone, be apparently the issue of the familiar face speaking, like a voice from the Arabian Nights, across the world? The Morses, the Bells, and the Edisons of coming years may be relied on to perform no less wonders than those which now astonish us; and the phonographs and graphophones of later days and of future ages will record in their own voices and their own language, for all the eternities of earth-existence, their thoughts and their triumphs, in dormant, but ever-living, form. The great electricians of to-day are teaching us how to convert the energy of the steam-engine into the newer form and to apply it to the illumination of our streets and our dwellings, and to employ it in the operation of all the machinery of shop and mill and home. The time may yet come when, by the employment of this wonderful conveyer of power, the energy of all the coal-mines, or of the immeasurable tons and tons of water pouring over that tremendous precipice of Niagara into the abysses of the whirlpool and the rushing rapids below—over three millions of horse-power—may be transmitted along a copper wire to distant cities to furnish the motive power of factories, of workshops, and of innumerable home industries, doing its share of the great work yet to be performed, of breaking up the present factory system and enabling the home-worker once more to compete on living terms with great aggregations of capital in unscrupulous hands. Great steam-engines will undoubtedly become generally the sources of power in our larger cities, and will send out over the electric wire, into every corner of the town, their Briarean arms, helping the sewing woman at her machine, the weaver at his pattern loom, the mechanic at his engine lathe, giving every house the mechanical aids needed in the kitchen, the laundry, the elevator, and, at the same time, giving light, and possibly even heat, in liberal quantity and intensity. It may become a more powerful genius than was ever dreamed of by Scheherazade, and described in the "Arabian Nights' Entertainments."

There are some other directions in which we may certainly hope to see as marvellous changes in the future as have been witnessed in the past. It is not impossible that we may see fleets of submarine boats doing the work of peace and of war. A century ago, nearly, Robert Fulton, following in the path opened by Bushnell still earlier, built in France a boat which, sailing about on the surface like any other craft, would then strike its sails and plunge beneath the surface, moving about at the will of its commander by the hour, would reappear where least expected, shake off the floods from its decks, and, raising its mast again, steadily sail across the sea to its destination. In our own days, my friend Holland, the most persistent, the bravest, and most reliable of inventors in this art, has built his submarine boats to carry himself and friends about the harbor of New York, spending the hours under water or on the surface, as he might choose, and showing his turtle-shaped deck at one time off the docks of the city, and, an hour or two later, astonishing and frightening the passengers of a steamer in the Lower Bay by his sudden rise alongside. Such boats will probably be used in submarine explorations, and will undoubtedly be employed in naval warfare, to the confusion of nations spending their millions upon the monster iron-clads now familiar to us. The limited experiences of our people during our own Civil War, with their rude "davids" of that time, showed what may be anticipated when these submarine craft are made capable of life at sea and of traversing long routes. Possibly we even may hope that the time will come when we, with some later Captain Nemo, may thus cross the Atlantic, unaffected by gale or wave, in comfort and safety, winter and summer alike. The problem is unquestionably in a promising state of semi-solution. When the submarine boat, the Howell or other torpedo, and the Zalinski gun are brought together in one such craft, the death of all naval warfare at a very early date is assured. The work of the inventor will insure the peace of the world.

Storage batteries, with their stored energy in the form of electricity, may be useful in submarine navigation and in the propulsion of carriages on land; and it looks as if they were likely at an early date to be of service in the solving of that greatest of all the visible problems of the engineer, the navigation of the air. For this purpose it seems possible that steam, too, may yet be of service, to at least a limited extent. It was shown, many years ago, by the distinguished French engineer Dupuy de Lôme that balloons might be made "dirigeable" by hand and impelled by power, and his work has been repeated in later years by the Messrs. Renard and Krebs, using stored electricity and attaining a speed of nearly fifteen miles an hour. An English engineer also, Mr. Pole, the veteran authority on applications of steam power, asserts that, taking the lifting power of the balloons as given by latest good work, and assuming that they may be propelled by engines no heavier than those sometimes employed in torpedo-boats, it would be possible to drive a cigar-shaped balloon, four hundred feet long and thirty feet in diameter, at the rate of thirty miles an hour. That this will be realized, and more, we may hardly doubt. But it remains a question whether the balloon can be dispensed with and the flying-machine made self-sustaining as well as self-impelling. This is greatly doubted by many; but it is impossible to say positively that it cannot be done.* We may possibly yet see the air navigated by flying-machines of enormous size, conveying passengers and important despatches, and perhaps light articles of merchandise, at rates of speed exceeding the flight of the swiftest birds; but few men of science or engineers imagine that such machines will ever become vehicles of general use, or as reliable as to time and dates as are the steamships or the railway trains of to-day. Should the inventor of the successful flying-machine ever come forward, he will meet with a welcome such as has rarely been accorded any one of his predecessors. He will have performed a more wonderful task than any one of them.

A still more wonderful work will be done by the genius, should he ever appear and should the thing be possible, who shall find a way of producing that beautiful and incomprehensible light emitted by the fire-fly or the glow-worm—a light which is without heat and illustrates probably the only known case of at least approximately complete transformation of vital or heat-energy into light without waste and at low temperature. Such a transformation occurs less perfectly in phosphorous combustion, and the hint given by the animal and by the mineral cannot be supposed to be quite beyond the limit of thought of coming discoverers and inventors. He who turns the glow-worm's light to the use and benefit of mankind will confer an inestimable boon upon the race. It seems perfectly reasonable to suppose that this, at least a problem already solved by Nature, is not entirely beyond the reach of the ever-fruitful mind of man. It would seem no more improbable that the chemist should detect the secret of the composition of the fire-fly's illuminant than it once appeared that he should ever effect the synthesis of madder and revolutionize a great industry. Not only would the solution of this problem be a benefit to the race, as giving them a most beautiful and mild light, but the conversion of heat or other energy into this form of light, without wastes, would result in the most extraordinary economy. It is estimated that, in the case of the more common forms of light-producing apparatus, not over 5 per cent. of the energy is made useful, the remaining 95 per cent. being wasted as heat, and worse than wasted, as the heat produced is always a source of annoyance and loss of health. He who shall give us the secret of the flashing out-of-door lights of the summer evening will enable us to secure twenty times as much light with a given expenditure of fuel as we now obtain, and will in that proportion both cheapen the production of light and reduce the amount of injury done by combustion. We boast to-day of our electric lights; but, this invention or discovery made, we shall have a far less expensive, though perhaps not more healthful, light.

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* Recent experimental investigations by Professor Langley, the distinguished astronomer and physicist, prove that the difficulties here met with are vastly less than had been previously supposed.

The direct conversion of heat into electricity, or the direct production of that fluid by the combustion of fuel, is another of those problems which are thought by many men of science to be possibly capable of solution, and some rather promising efforts have been made to reach a result so attractive. This may even prove to be the true solution of the problem of the glow-worm. Should the time ever come when, by the burning of a little coal in our houses, we may at once heat them comfortably, derive all the power needed to do the domestic drudgery, secure a beautiful moon-like light, and preserve them, at the same time, against sensible vitiation of the atmosphere, we shall have attained a state of beatitude which might well be taken as a foretaste of paradise. We can, and actually do, transform heat and other energies already within our own bodies at a constant temperature: why may we not repeat these processes outside of them ? It does not seem possible that we must always submit to the now inevitable thermal and thermo-dynamic waste of three-quarters to nine-tenths, or more, of the stored energy of our fuels.

We can, at best, only speculate about these coming blessings of a future time and the coming race; but we may, at least, be permitted to hope that much of this possible may become actual. We may be allowed to hope that later generations may continue to see an interminable succession of advances made by coming men of science, and by learned engineers and mechanics, that shall continually add to the sum of human happiness in this world, and make it continually easier to prepare for a better world and a brighter. Who knows but that the telescope, the spectroscope, and other as yet uninvented instruments may aid us in this by revealing the secrets of other and more perfect lives, in other and more advanced worlds than ours, despite the head-shaking of those who know most of the probabilities ? Who can say that the life of the race may not be made in a few generations, by this ever-accelerating progress of which the century has seen but the beginning, a true millennial introduction into the unseen universe and the glorious life that every man, Christian or sceptic, optimist or pessimist, would gladly hope for and believe possible ? Of this we may be certain : no one can imagine the reach and limit of the results of the application of the intellect of man to the problems of life to-day, any more than could our ancestors of two centuries ago have imagined or believed in the progress that we to-day may look back upon. The border-land of science still stretches on into the unknown.

R. H. THURSTON.